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Key technology of brand-new 1.5L 3 cylinder engine for 3rd generation series hybrid powertrain - (Second Report) Fuel economy improvement -

Taichi Ando [1)] Isei Matsuzaki [1)] Yukiyo Yamada [1)] Akihiro Shikata [1)]

1) Nissan Mortor Co., Ltd.
560-2 Okatsukoku, Atsugi, Kanagawa, 243-0192, Japan (E-mail: taichi-a@mail.nissan.co.jp)

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To achieve further improvements in fuel economy, a brand-new 1.5-L three-cylinder turbocharged engine (ZR15DDTe) dedicated to the third-generation 100% electrically driven series hybrid powertrain (i.e. e-POWER) has been developed. The engine is optimized exclusively for power generation and has achieved a maximum brake thermal efficiency (BTE) of 42%. While the application of a high exhaust gas recirculation (EGR) rate of up to 25% contributed significantly to this achievement, it also introduced new technical challenges, most notably condensed water formation in the intake system. In addition, improving thermal efficiency during engine warm-up under vehicle operation was identified as a key requirement for further fuel economy gains.

Condensed water is generated when water vapor originating from both fresh intake air and recirculated exhaust gas is cooled below its saturation condition after turbocharging and charge air cooler (CAC) cooling. To address this issue, a physical model was developed to predict the amount of condensed water based on intake gas composition, EGR ratio, CAC outlet temperature, and pressure. The model employs molar fractions to describe gas composition and incorporates combustion stoichiometry, enabling the influence of different fuel properties, including oxygenated fuels, to be considered. From this model, a limiting EGR ratio that prevents condensed water formation was derived and implemented as a control strategy using existing on-board sensors. This model-based control enables robust suppression of condensed water under all environmental conditions while minimizing restrictions on EGR usage and associated thermal efficiency losses.

Improving thermal efficiency during the warm-up phase was also addressed through optimization of both the thermal system and engine operation. The ZR15DDTe is equipped with a dual coolant system consisting of high-temperature (HT) and low-temperature (LT) circuits. A flow shut valve was introduced in the HT circuit to reduce effective thermal capacity during cold operation, accelerating coolant warm-up. In the LT circuit, control of the radiator bypass valve was optimized to raise the temperature range in which EGR can be applied early after start-up, while still ensuring sufficient cooling performance at high load conditions.

Furthermore, because the engine is mechanically decoupled from vehicle driving demand in the e-POWER system, engine operating points can be freely selected. This characteristic was leveraged to maintain high thermal efficiency during warm-up by adjusting engine torque according to the EGR limitation derived from the condensation model. Lowering engine torque reduces intake pressure, which in turn allows higher EGR rates under the same temperature and humidity conditions.

Vehicle tests incorporating these technologies demonstrated a clear improvement in real-world performance. Compared with the previous generation engine, an approximately 8% improvement in the frequency distribution of thermal efficiency during WLTC driving was achieved, validating the effectiveness of the proposed approaches.

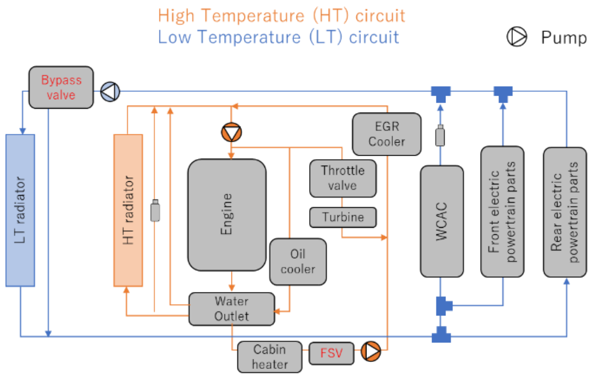

Fig. 1 The schematic diagram of HT and LT thermal circuit

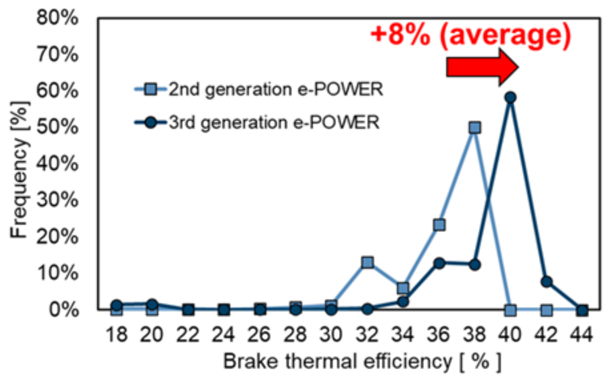

Fig. 2 Frequency of thermal efficiency during WLTC mode

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